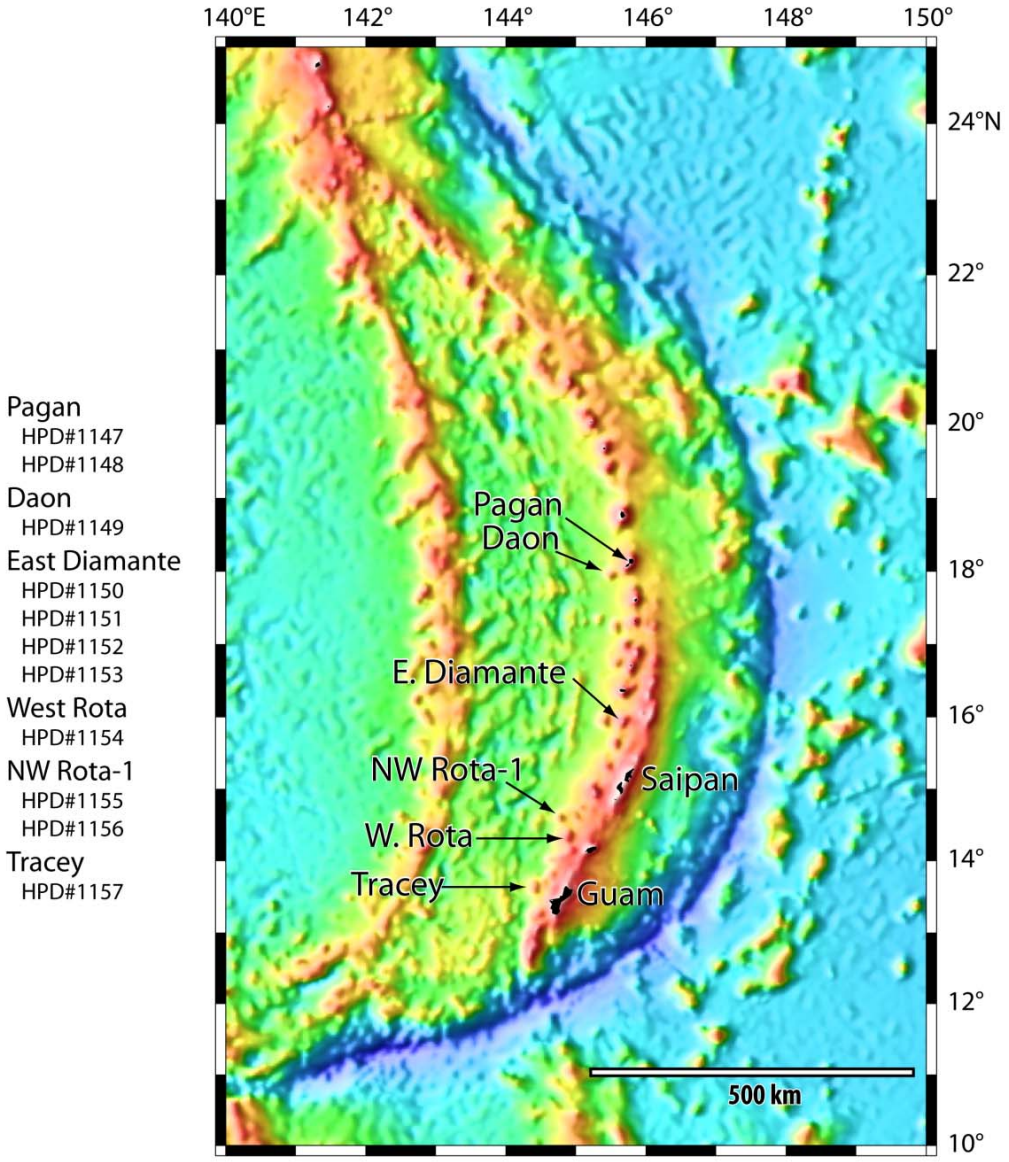
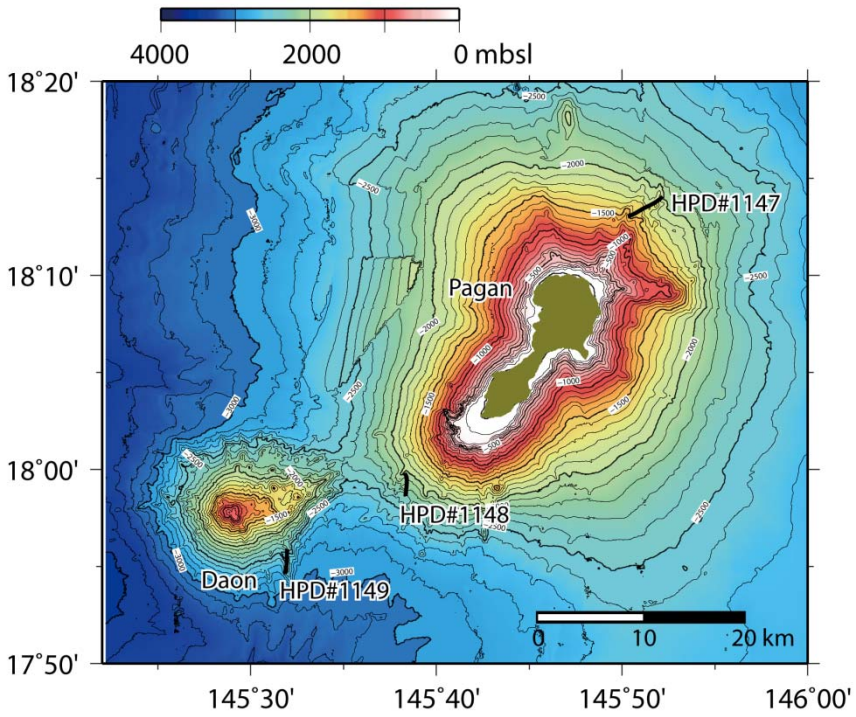
NT10-12 Cruise Summary

1. Cruise Information

Cruise number	NT10-12
Ship name	Natsushima/Hyper-Dolphin
Title of the cruise	Mariana Waters (NT10-12)
Chief Scientist	Yoshihiko Tamura (IFREE, JAMSTEC)
Representative of Science Party	Yoshihiko Tamura (IFREE, JAMSTEC)
Title of proposal	Mariana arc volcanoes from latitude 13°N to 18°N: a comprehensive study of an oceanic arc
Cruise period	July 9, 2009 ~ July 19, 2010
Port call	Guam to Guam



ROV Hyper-Dolphin dives and bathymetric surveys in the Southern Mariana region were carried out during NT10-12 cruise (R/V Natsushima) between July 8 and July 19, 2010. A total of 11 dives (HPD#1147~HPD#1157) were focused on the submarine volcanoes within the Pagan-Daon cross-arc chain, and at East Diamante, NW Rota-1, West Rota and Tracey. Previous work in the Izu-Bonin-Mariana arc has shown that small parasitic cones on the flanks of larger volcanoes often yield more mafic lavas than the main edifice. That is certainly true of Pagan, Daon and Tracey, where mostly undifferentiated olivine-bearing basalts were recovered from their lower flanks. These samples will be compared with primitive lavas from NW Rota-1, where two primary magma types have been found. NW Rota-1 is known to have two main types of primitive basalt, COB and POB, which represent clinopyroxene-olivine basalt and plagioclase-olivine basalt, respectively.



Pagan Island is one of the active volcanoes in the Central Island Province of the Mariana magmatic arc. Pagan is elongate roughly NE-SW and the southern end of the island is inactive, steep, and eroded. The northern end is active and was producing small clouds of steam and ash during operations for HPD#1147. The northeastern slopes of Pagan show a NNE trending rift zone with several small parasitic cones. This rift and the associated cones were the targets for HPD#1147, in water depths of 2000-1500 m, which were found to mainly consist of basaltic pillow lavas. For example, Hyper-dolphin came into outcrops with spectacular pillows and pillow tubes (see Fig. 4, Fig. 5A, B of HPD#1147). There were large

pillows, with strongly striated outer surfaces and concentric cooling cracks, and long pillow tubes with similar outer surfaces. Some of the pillow tubes were clearly elongate down-slope. Sediment cover was very light in most of the section.

The south end of the Pagan Island is inactive, with steep eroded slopes. As with dive HPD#1147, HPD#1148 was planned to investigate small parasitic cones and a ridge to the southwest of Pagan, east of the cross-chain Daon Seamount. The principal goal was to characterize and sample the eruptive products on the southwest slopes of Pagan and determine how these compared with those to the northeast. The traverses produced quite different results: the lava flows are less obviously pillowed, considerably older, and the sediment cover was considerably more extensive. The rocks recovered generally displayed greater alteration, no glass, and many were considerably more porphyritic and less vesicular than the younger rocks recovered from the northeast of Pagan.

Daon seamount is a "behind-the-magmatic-front" (cross-chain or rear-arc) volcano associated with Pagan. No volcanic or hydrothermal activity is known. Daon's summit rises from a base ~3000-3200 m to a summit that lies less than 900 m b.s.l. In map view, the edifice is elongated E-W, 20 km E-W and ~15 km N-S. Bloomer *et al.* (1989) calculate a volume of 150 km^3, ~10% of the size of the largest Mariana volcanoes such as Pagan and Agrigan. Daon merges across a ~2500 m deep saddle with the SW extension of S. Pagan. Daon has an unusual morphology, with many ridges radiating from it, which may reflect the presence of radiating dikes. No studies are reported for Daon, although Bloomer *et al.* (1989) dredged the SW part of the edifice, recovering dacites with phenocrysts of plagioclase, hornblende, clinopyroxene, and orthopyroxene. Some of these samples contained disseminated sulfides. Our principal goal in the dive HPD#1149 was to characterize and sample the eruptive products on the lower eastern slopes of Daon. The dive was planned in a series of three traverses, the first two on the longest southward trending ridge on the south side of the volcano at depths of 2580 to 2470 m. b.s.l., and the third on the south-facing slope of a short but steep ridge to the north, at depths of 2520-2320 m.b.s.l. Samples recovered were fairly homogeneous, all 18 rock samples are basalts; 11 are described as olivine basalts, 2 are olivine-clinopyroxene basalts, the remainder are aphyric basalts. All samples had some Mn coating, ranging from almost nothing to 10 mm thickness.

East Diamante seamount lies about 80 km north of Saipan and is the northernmost volcano of the Southern Seamount Province of the Mariana magmatic arc. Moreover, East Diamante is located on the volcanic front side of the Diamante cross-arc chain and has a complex volcanic history. East Diamante is an irregular caldera about 10 km x 4 km that is breached on the north and south sides. The caldera floor has a maximum water depth of about 700 m. After caldera collapse, dacitic domes intruded into the center of the caldera providing the heat source for production and circulation of hydrothermal fluids that generated the large mounds field and two nearby chimney fields, one active and one inactive, found in 2004

during a NOAA Ring-of-Fire cruise. An elongate field of hydrothermal mounds was discovered along the NE flank of a cluster of resurgent dacite domes in East Diamante Caldera using the ROV Hyper-Dolphin aboard the R.V. Natsushima in June 2009 and July 2010. The mounds field is more than 100 m long and about 25-30 m wide and occurs along a NE-SW rift valley at water depths of about 365-400 m b.s.l. Individual hydrothermal mounds and ridges along this trend vary in size and the bases of the mounds are buried beneath hydrothermal sediment so that only minimum dimensions can be determined. Mounds are typically 1-3 m tall and 0.5-2 m wide, with lengths of about 3 to more than 5 m. The sulfide/sulfate mounds are layered and an iron- and manganese-oxide subsidiary mound venting low-temperature fluids caps some of them. Some mounds also support inactive sulfide/sulfate chimneys and spires; chimneys rarely occur as independent structures within the mounds field. The mounds are composed primarily of barite layers and sphalerite (high cadmium, low iron) plus galena layers with up to 470 ppm silver and 3 ppm gold. Several age dates for one mound show the layered section to have formed about 4,000 years ago while the subsidiary oxides formed during the past 4 years.

West Rota volcano is the largest submarine caldera in the Mariana arc. The eastern caldera wall preserves much of the stratigraphic and intrusive relationships. West Rota consists of a lower, predominantly andesite, section overlain by a bimodal rhyolite-basalt layered sequence. In our ROV studies of HDP#1154, intensely hydrothermally altered and mineralized rocks have been observed and collected in the lower caldera wall.

Tracey Seamount lies about 30 km due west of Guam and is the southernmost substantial volcano of the Mariana magmatic arc. With an estimated volume of 45 km^3, Tracey is one of the smaller volcanoes along the Mariana magmatic arc (compare with Pagan with a volume of 2200 km^3, Bloomer et al, 1989). Tracey forms a perfect cone that rises over 2 km, to a water depth of 750 mbsl, and has a diameter of approximately 7 km at the 3000 m water depth contour. At the present day Tracey is believed to be extinct, with no eruptive or hydrothermal activity having been recorded. The western side of the summit is dissected by a sector collapse crater, within which a resurgent dome formed. Tracey Seamount was first visited by ROV in dive HPD#949, cruise NT09-02, which traversed up the resurgent dome and west-facing, eastern wall of the crater. The dome was found to consist of dacite and one of the samples collected has been dated at 500 ka. The dome is believed to be the youngest magmatic event at Tracey. The crater wall is made up of basaltic andesites to andesites, volcaniclastics and pumiceous sandstone that becomes increasingly prevalent towards the top, and a cap of pumice. This suggests that Tracey erupted increasingly evolved material. Unusually for the Mariana Arc, where most rocks are medium-K, Tracey appears to erupt low-K material. The trace element signatures of the felsic and mafic magmas of Tracey make it impossible to relate them by fractional crystallization. HPD#1157 dive aims to recover material from the lower slopes of the edifice and thus from earlier in the evolutionary history

of Tracey than the samples recovered to date, allowing the geochemical characteristics of Tracey volcano to be investigated further. The lower slopes of this part (2790-2450 m water depths) of Tracey Seamount appear to be constructed of basalt, with some pumice that may be in situ, suggesting bimodal volcanism, although an exotic origin cannot be ruled out. The cone sampled in the first traverse appears to consist of basalts with a phenocryst assemblage of olivine + plagioclase + clinopyroxene. In the higher slopes the clinopyroxene is absent from the basalts' phenocryst population, and the rocks are more olivine-rich, almost picritic. In the highest part of the slope sampled in this dive the basaltic rocks are less porphyritic and more vesicular. Together with the observations made and samples collected during dive HPD#949, the samples collected in this dive suggest that Tracey Seamount is largely a basaltic edifice, although there may have been minor amounts of more explosive felsic volcanism that produced pumice. Towards the end of Tracey's eruptive history felsic volcanism became more dominant.